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14. ABSTRACT
A vertical structure finite volume model has been developed to study density and turbidity current in the coastal ocean. The model incorporates different turbulence closure schemes. The model successfully simulates the generation of internal waves due to the passage of a density current in a stratified medium. Model results also show that at the laboratory scales different turbulence closure schemes lead to the prediction of fairly similar results.

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Modeling the Impact of Extreme Events on Margin Sedimentation

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LONG-TERM GOALS

To understand the mechanics of hyperpycnal flow generated from the plunging of small and medium size rivers and how these extreme events affect the transport of terrestrial sediment and how they influence the mixing processes in the coastal ocean.

OBJECTIVES

- To develop a two dimensional vertical structure finite volume model of density and turbidity current with different turbulence closure models.
- To verify this model against available experimental data.
- To apply the model at the field scale to study the affect of stratification on a plunging density current.
- To study the generation of internal wave by the passage of a hyperpycnal flow (turbidity current).

APPROACH

A two-dimensional vertical structure model has been developed. This model solves the Reynolds-averaged Navier-Stokes (RANS) equations along with species mass conservation equations for non-orthogonal structured grid in order to obtain flow variables that are non-uniform over depth. Closure for the turbulence stress terms is obtained by using the buoyancy modified k-ε model, one equation k-l model, one equation q^2-l model, and the two-equation q^2-q^2l model. In the one equation turbulence models, the turbulent kinetic energy or the turbulent velocity scale is obtained by solving a transport equation while the length scale is obtained using an algebraic equation (e.g. Adams and Weatherly 1981). The governing equations are discretized using an implicit finite volume scheme for non-orthogonal grid system. Bed level change is simulated by solving the Exner equation of bed sediment continuity. The numerical grid is adjusted during each time step due the elevation change of the bottom boundary in response to sedimentation and erosion.

The work has been primarily carried out by a doctoral student Sadia M. Khan and it contributes to her dissertation.

WORK COMPLETED

- A 2-D vertical structure finite volume model of density driven flow has been developed. The numerical model incorporates different turbulence closure schemes. A non-orthogonal grid system has been used in the model that can handle a wide variety of boundary conditions.
- The model accounts for bed level changes due to sediment entrainment and deposition. The grid is adjusted during the computation to account for bed level changes.
- The model has been verified against experimental data on the vertical structure of turbidity current. The model simulates the experimental results satisfactorily with different turbulence closure.
- The model has been used to study the generation of internal waves by the passage of a density current in a stratified medium at the laboratory scale.

RESULTS

The model has been utilized to study the generation of internal waves from the passage of a density/turbidity current at the laboratory scale. For this purpose, we have considered two sets of experiments carried out by Maxworthy et al. (2002) and Monaghan et al. (1999). In the first experimental setup, internal waves have been generated by density current in a tank with horizontal bottom (Maxworthy et al. 2002). They have run several experiments for sub- and super-critical flow conditions where heavy fluid was released from behind the lock gate to the lower boundary of the tank containing linearly stratified ambient fluid. The second set of experiments carried out by Monaghan et al. (1999) generated internal solitary wave when density current was descending down a ramp into a two-fluid system. We have run our model using these two experimental setups and found that model predictions are in good agreement with the experimental results. Figure 1 shows the comparison of some of the model result with the experimental results of Maxworthy et al. (2002).

The model has been also verified by comparing the simulated vertical structure of turbidity current with experimental measurement. For this purpose, we have considered one of the experimental data sets generated by Garcia (1990). We have run our model with different turbulence closure schemes for the experimental run DAPER6. Figure 2 shows the comparison of the model results with the experimental data of Garcia (1990). It can be seen here that at the laboratory scale, the predicted profiles obtained using different turbulence closure schemes are fairly close.

IMPACT/APPLICATIONS

The development of the numerical model of density/turbidity current provides an opportunity to study the impact of density driven flow on the seabed morphology and the mixing process in the coastal ocean due to the passage of turbidity current. Turbidity currents can be generated by retrogressive slope failure, storm, or due to the plunging of a river. The non-depth-averaged model developed here allows us to study the vertical structure of compositional and particulate density driven flows which commonly occur in the ocean environment.

RELATED PROJECTS

This project is closely related to an NSF funded project "CAREER: Experimental and Numerical Modeling of Flow and Morphology Associated with Meandering Submarine Channels" and an industry funded project "3-D Numerical modeling of turbidity current."

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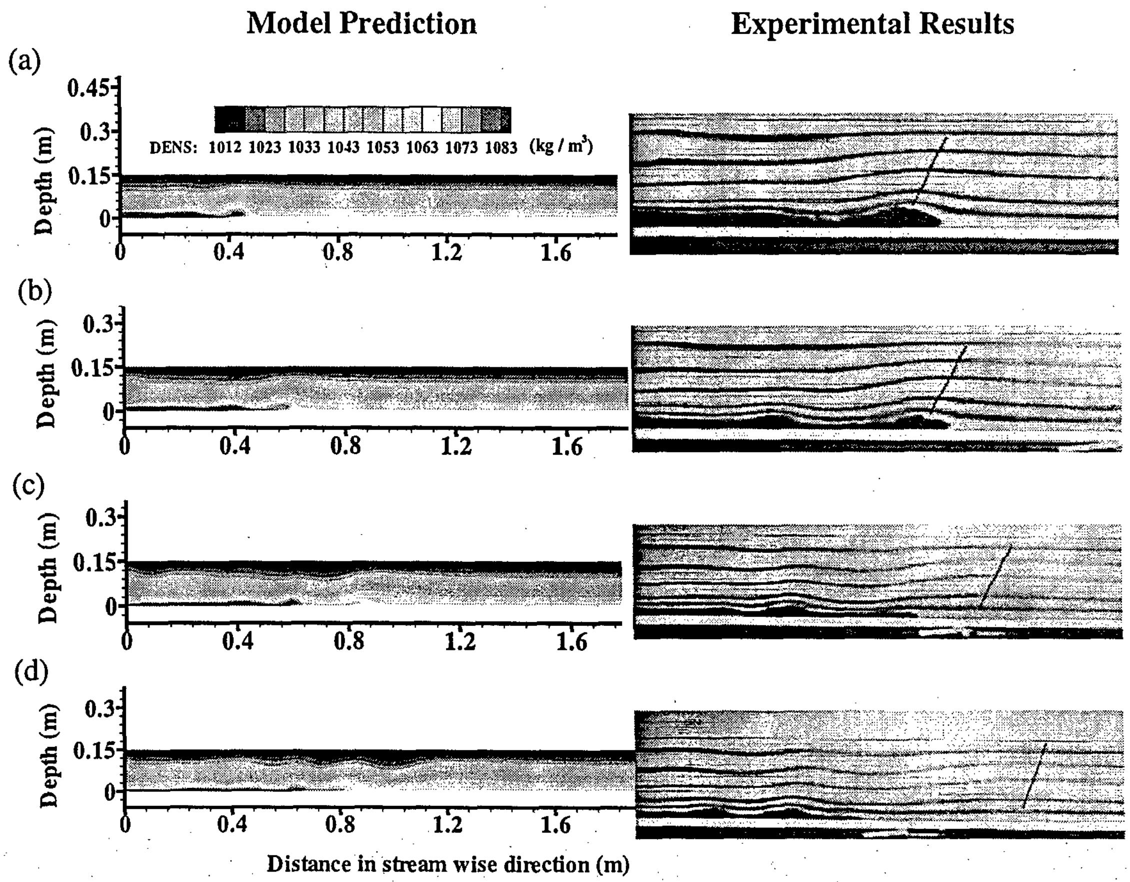

Figure 1. Comparison of the model prediction with experimental results. Left: simulation; Right: photographs from experiment of Maxworthy et al. (2002). Time sequences are (a) 4s; (b) 6s; (c) 10s and (d) 12s after opening the gate.

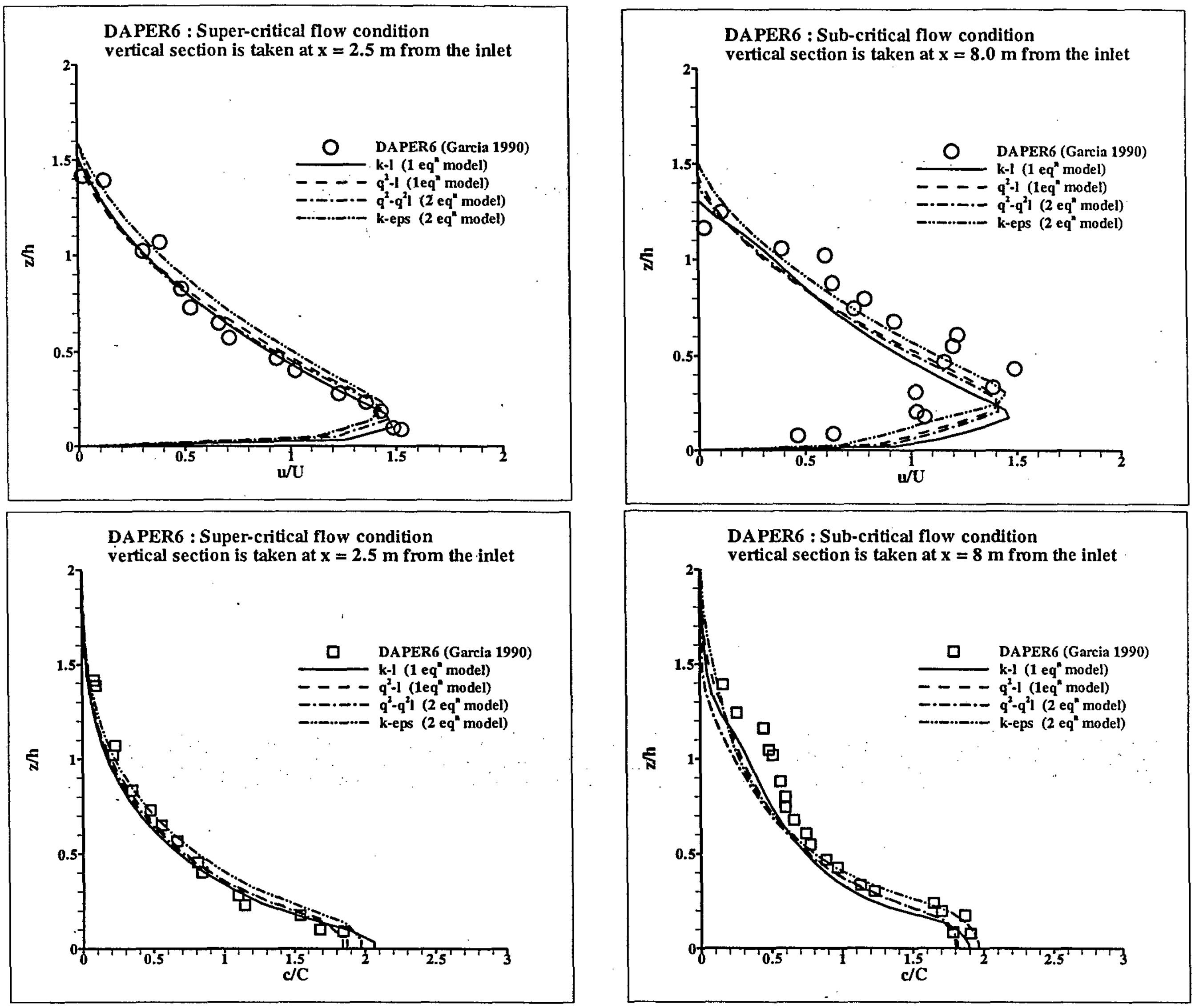

Figure 2. Comparison of the model prediction with experimental results. Left: supercritical flow on a ramp. Right: subcritical flow on a horizontal bed.